Nuclear Electric Propulsion Options for Piloted Mars Missions

Nuclear Propulsion Technical Interchange Meeting
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NEP for SEI Mars Missions

- Synergy with Surface Power Technology
- "Fast" Piloted Missions
- Efficient Cargo Delivery
- Fewer and/or Smaller (135 MT) Launch Vehicles
- Continuous Abort Mode
- Continuous Earth Return Window
- Technology:
  - Existing Reactor Technology Program
  - Need Potassium Rankine Power Conversion
  - Need Multimegawatt Ion Thrusters

Why not NEP?

- Long Earth spiral escape times
  - Impractical piloted lunar missions
  - Chemical crew taxi for piloted Mars
- Long operating times
  - High reliabilities necessary
  - Complications for artificial gravity
- Multiple technologies
  - Reactor
  - Power Conversion
  - Thrusters

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NEP Technologies

- Reactor
  - 2 yr life, 25 MWth SP-100
  - Li cooled, fast spectrum, UN fuel, Nb-1Zr clad
  - Technology developed in current SP-100 program
- Power Conversion
  - 1400 K Potassium Rankine
  - SNAP-50 tested components at 1420 K for 10,000 hours
    - 3-5 life projected from turbine erosion
- Thrusters
  - Argon ion engines, 5000 sec. Isp, 69 % efficiency, 10,000 hour life
  - Efficiency and life demonstrated at Isp but lower power
  - EP will be used on upcoming Telstar IV

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2 x 5 MWe Reduced Life Growth SP-100 NEP System

Reactor	Li-cooled pin-type fast reactor
Power Conversion	Potassium Rankine
Power Output	5 MWe/Module
Full Power Life	2 yrs
Propulsion	Ion
Cycle Characteristics:	
Turbine Inlet Temp.	1400 K
Condenser Temp.	975 K (Min. mass)
Thermal-Electric Eff.	20.5 %
Reactor:	
Spectrum	Fast
Coolant	Lithium
Fuel	UN pins
Cladding	PWC-11
Structure	PWC-11
Man-rated Shadow Shield:	
Dose Constraint	5 rem/yr
Materials	W / LiH
Dose Plane Diameter	20 m
Separation Distance	100 m
Heat Rejection:	
Type	Heat Pipe Radiators
Geometry	Planar
Specific Mass	6 kg/m2
Total Radiator Area	693 m2/Module

System Mass Breakdown:

Reactors	6990 kg
Shielding	12200 kg
Power Conversion	19060 kg
(4+2 T-G units, 50% redundancy)	
Radiators	8320 kg
Power Cond. & Dist.	20000 kg
Ion Propulsion	6000 kg
Total (2 Modules)	72570 kg
Specific Mass	7.3 kg/kWe

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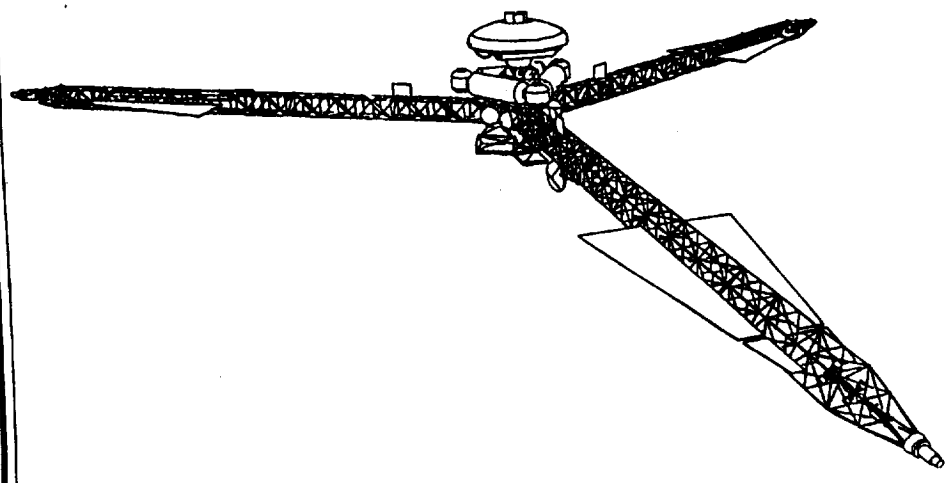
15 MWe Multi-Reactor Nuclear Electric Propulsion Vehicle for a Piloted Mission to Mars



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Groundrules

- Systems
  - Modular/Multiple Power Systems
    - Growth SP-100 Reactor
    - 1400 K Potassium Rankine Power Conversion
  - Argon Ion Engines
    - 5000 sec Isp
    - 68.9 % efficiency
    - 10,000 hour life
  - 7.3 kg/kWe
  - 10 % Tankage Fraction
  - 10 MT Inerts/Structure Mass
- Orbits
  - SSF Altitude Earth Departure Orbit
  - Crew boards at HEO
  - Areosynchronous Orbit at Mars
  - ECCV return at Mars (9.4 km/sec V_∞ Limit)

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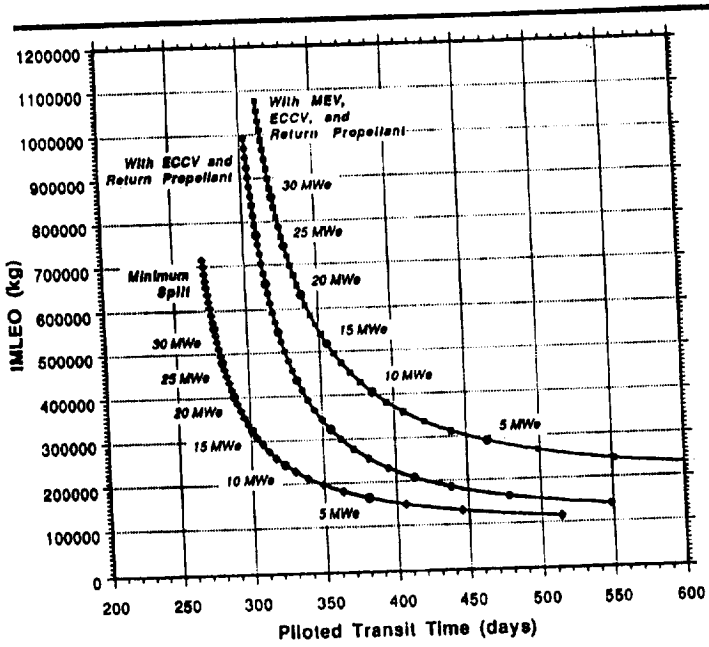
Payload Assumptions

ECCV	7 MT
Transit Habitat	55 MT
Piloted MEV	65 MT
Cargo MEV	65 MT

- Unless otherwise noted - all Piloted NEP missions presented carry return propellant

Conjunction Mission Performance for the 2010 Mission Opportunity



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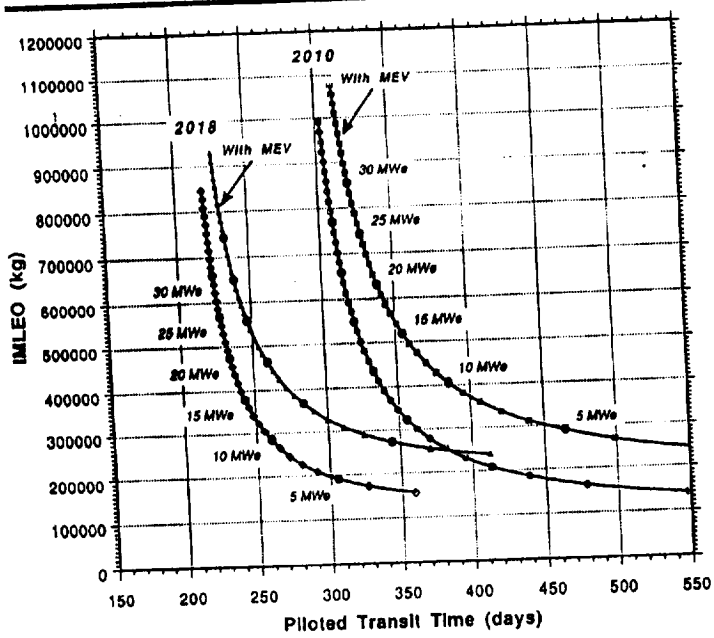
Conjunction Mission Performance over Various Opportunities



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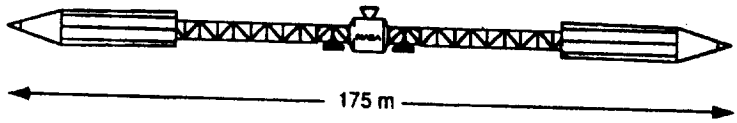
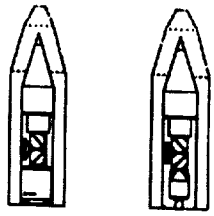
10 MWe Piloted Mars NEP with ECCV

2 x 5.0 MWe Modular "Hydra" NEP Vehicle



2 x 181 MT HLLV Launches



179 MT	181 MT
41 m x 8 m	41 m x 8 m

	2010	2018
Piloted Transit Time:	193 d +180 d 373 d	154 d +106 d 260 d
IMLEO:	310 MT	285 MT

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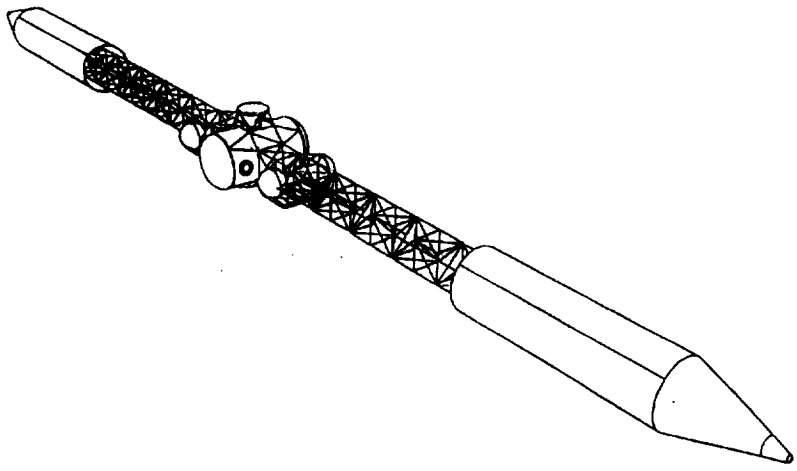
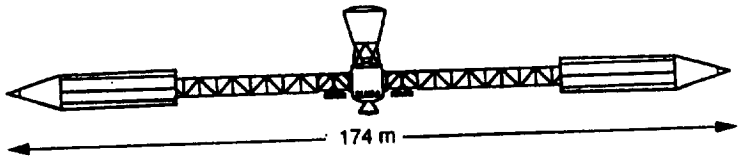
10 MWe Modular NEP Piloted Mars Vehicle

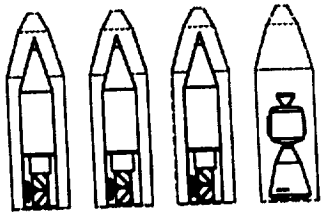


10 & 15 MWe Piloted Mars NEP with ECCV & MEV

2 x 5.0 MWe Modular "Hydra" NEP Vehicle



3-4 x 132 MT HLLV Launches



116 MT
41 m x 8 m

132 MT
25 m x 10 m

	2010*	2018
Power:	15 MWe	10 MWe
Piloted Transit Time:	200 d +180 d 380 d	177 d +106 d 283 d
IMLEO:	479 MT	367 MT

* - Optimal leg distribution 221+134=355 d & 518 MT

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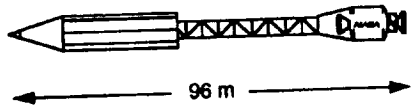
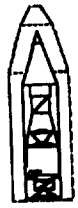
5 MWe Piloted Mars NEP with ECCV

5.0 MWe Piloted NEP Vehicle



1 x 190 MT HLLV Launch



190 MT
41 m x 8 m

	2010	2018
Piloted Transit Time:	233 d +200 d 433 d	181 d +125 d 306 d
IMLEO:	189 MT	190 MT

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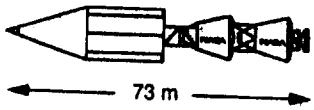
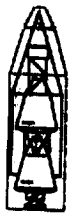
5 MWe Mars Cargo NEP with 2 MEVs

5.0 MWe Cargo NEP Vehicle



1 x 242 MT HLLV Launch



242 MT
46 m x 12 m

	2007 One-Way
Transit Time:	418 d
IMLEO:	242 MT

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2.5 MWe Mars Cargo NEP with MEV

2.5 MWe Cargo NEP Vehicle

1 x 135 MT HLLV Launch

135 MT
46 m x 10 m

	2007 One-Way	2007 Round Trip
Transit Time:	405 d ±0 d 405 d	460 d ±209 d 669 d
IMLEO:	135 MT	135 MT

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Launch Vehicle Requirements

Launch Vehicle Size	Mission Mode	Piloted	Cargo	Total
"Small" (135 MT)	10 MWe Piloted with ECCV	3	4	7
	10/15 Piloted with MEV	3-4	3	6-7
"Medium" (180 MT)	5 MWe Piloted with ECCV	1	4	5
	10 MWe Piloted with ECCV	2	4	6
	10/15 Piloted with MEV	3-4	3	6-7
"Large" (220 MT)	5 MWe Piloted with ECCV	1	2	3
	10 MWe Piloted with ECCV	2	2	4
	10/15 Piloted with MEV	3-4	2	5-6

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Future Work

- Preliminary trade studies completed
  - EXPO '92 NEP Mars Scenario
- Select reference mission/system scenario
- Perform focused studies
  - System design
    - Krypton propellant
    - Advanced reactor/power conversion technologies
  - Launch manifest
  - Aborts/Window Assessment
  - 10 MWe out/15 MWe back
  - Radiation Protection

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Summary

- NEP meets EXPO trip time requirements (5-10 MWe)
- NEP enables reduction of number and/or size of HLLV's
- NEP has inherent flexibilities and abort capabilities not afforded by high thrust systems
- Synergy exists between NEP, surface, and spacecraft power technologies
- NEP could be ready to support 2010 Mars mission - No technological "show-stoppers" exist

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